Study of the Carbon Growth Mechanism in Varying Dose and Surface Conditions of Witness Sample under EUV and EB Exposures

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Objective and Method of this work

Objective

1. Examine the relation of exposure dose for resists and Witness Samples (WS) for contamination limited condition of carbon growth (CG).
2. Compare them in different resists having different outgassing species and amounts.
3. Check the effect of WS surface material and roughness for carbon deposition rate.

Method

1. Contamination-limited condition was investigated by Electron-beam outgas tester EUVOM-9000. The results were compared for two resist samples which shows different RGA spectrum and much different outgassing amounts.
2. Carbon deposition rates on Ru-top and Si-top WS were directly observed by In-situ ellipsometer equipped with EUV outgas tester HERC. The surface roughness of WSs were evaluated by AFM and X-SEM.

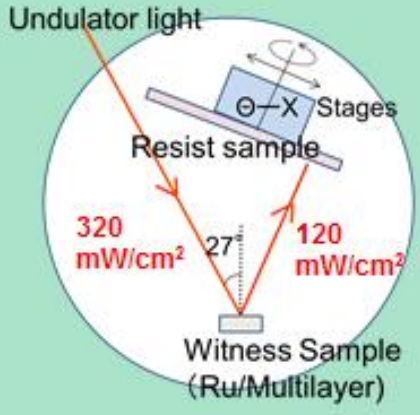
EUV and Electron Beam (EB) Outgas Tester

High Power EUV

HERC analysis tool

(High power EUV Resist Contamination)

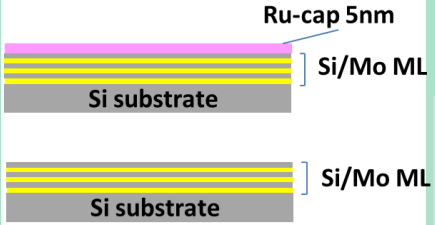
Synchrotron Irradiation
(@ NewSUBARU BL9c)



Source : EUV

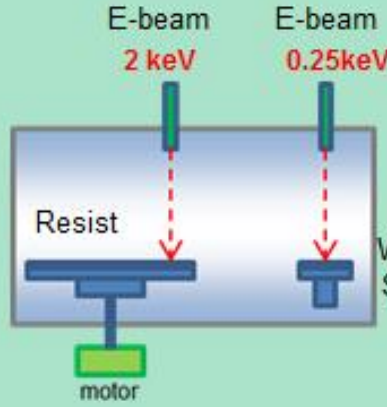
Vacuum :
Base 3~5 E-6 Pa

Witness Sample



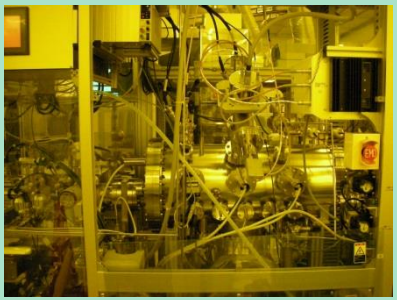
Electron Beam

EUVOM-9000

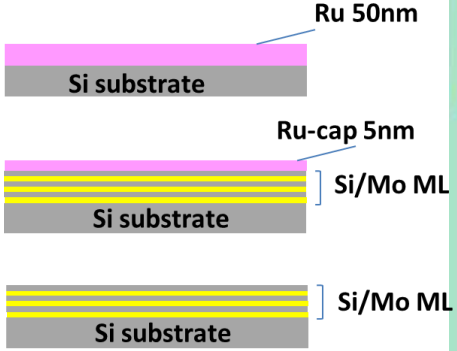


Source : E-beam

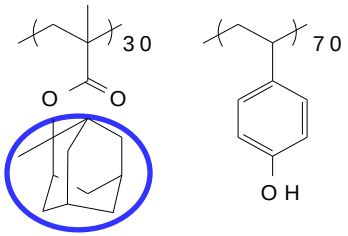
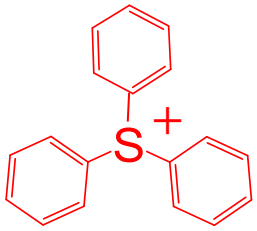
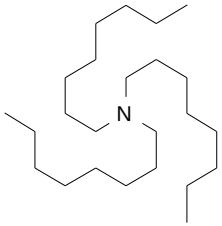
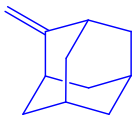
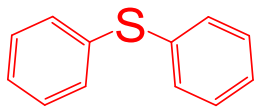
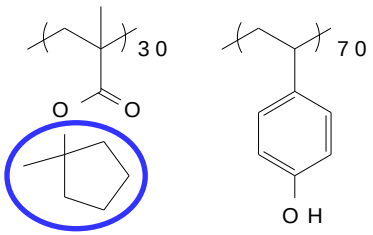
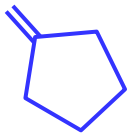
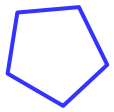
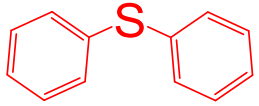
Vacuum :
Base 5~7 E-7 Pa



Witness Sample

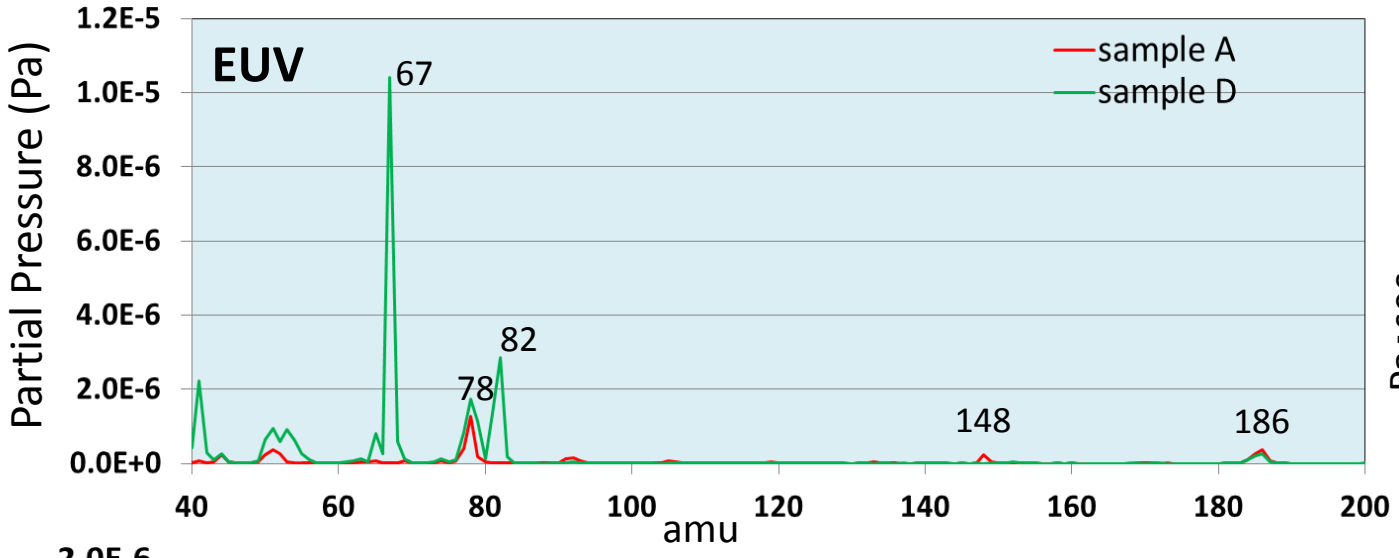


Resist Samples evaluated in this Study

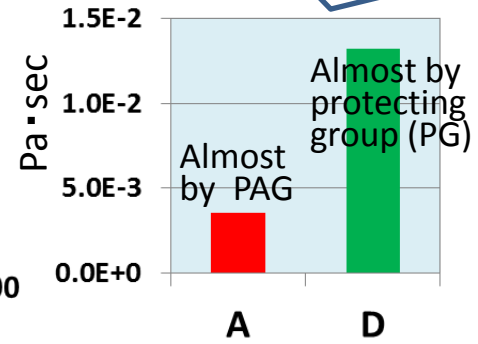
Resist Sample	Polymer & Protecting Group (PG)	PAG(20wt%)	Quencher	Main Outgassing species found by RGA
A*	 **Methyl Adamantyl**	 $C_4F_9SO_3^-$ **Triphenylsulfonium Nonaflate**	 **Tri-n-octylamine**	 amu 148  amu 78  amu 186
D*	 **Methyl Cyclopentyl**			 amu 82  amu 67  amu 78  amu 186

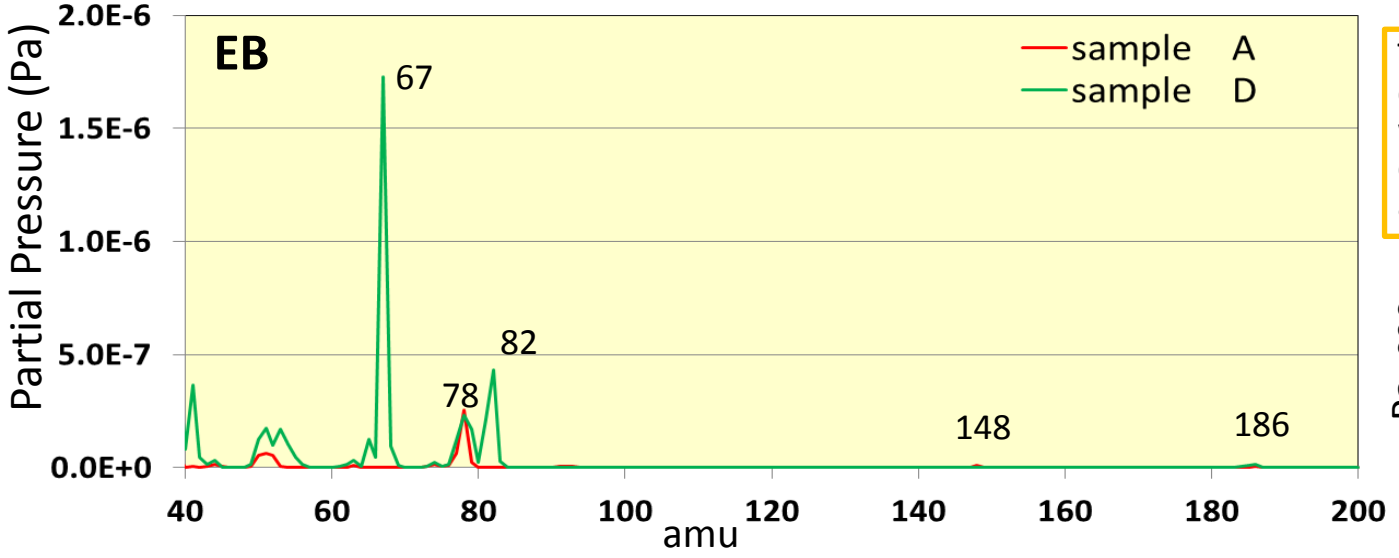
*Sample A and D corresponds to the sample with the same name in the paper of I. Takagi presented at oral session 7, Oct. 28.

RGA Spectrum and Total Outgas during EUV and EB exposure

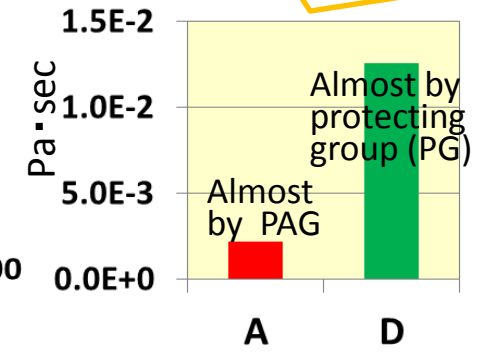


Total outgas during the EUV exposure. (amu50-200 in RGA were summed for the exposure time with 2.5*Eo on a 200mmϕ wafer)





Total outgas during the EB exposure. (amu50-200 in RGA. were summed for the exposure time with 1*Eo on a 300mmϕ wafer)



- RGA spectrums by EUV and EB are same for A and D.
- Total outgassing amount of D is much larger than that of A.
- Most of outgassing of sample A comes from PAG, but that of D comes from PG.

CG profile vs. Exposure condition in sample A and D by EB outgas tester

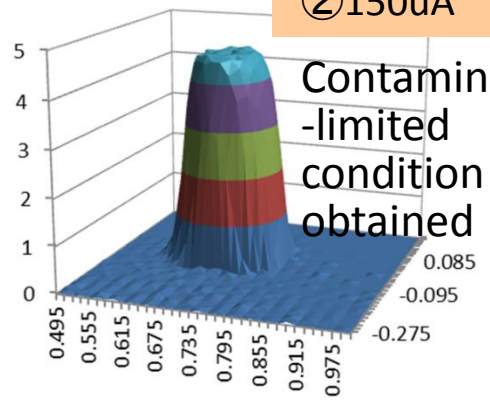
Exposure Dose on ①Resist Sample ②Witness Sample (Ru-top) **were changed**

① small — Impinging Outgas on WS — large

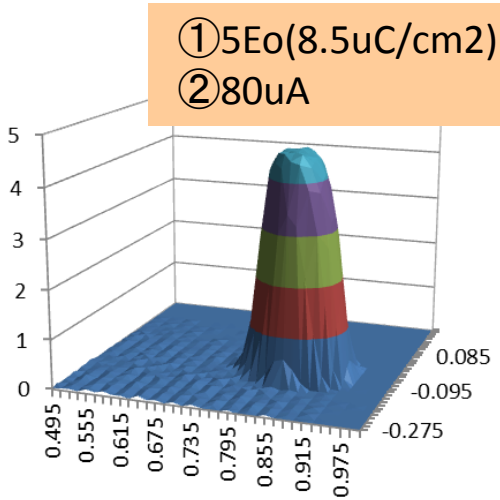
② large — Electron Density on WS — small

Sample A

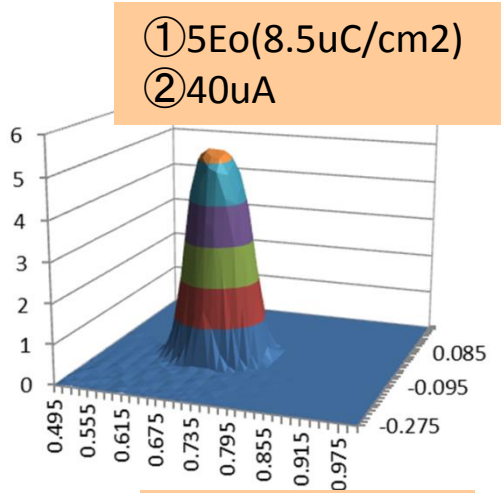
①Eo(8.5uC/cm2)
②150uA



①5Eo(8.5uC/cm2)
②80uA

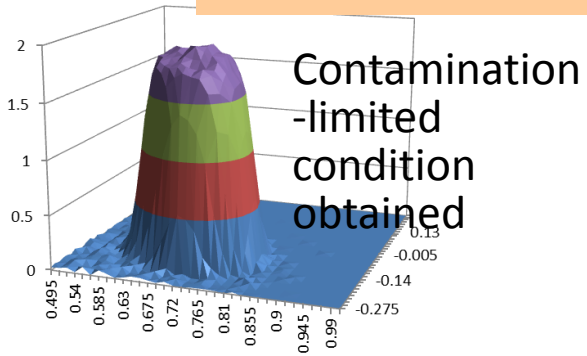


①5Eo(8.5uC/cm2)
②40uA

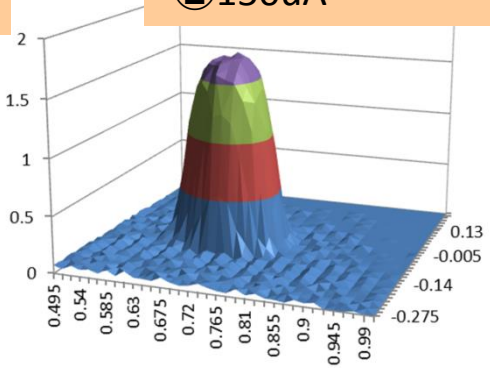


Sample D

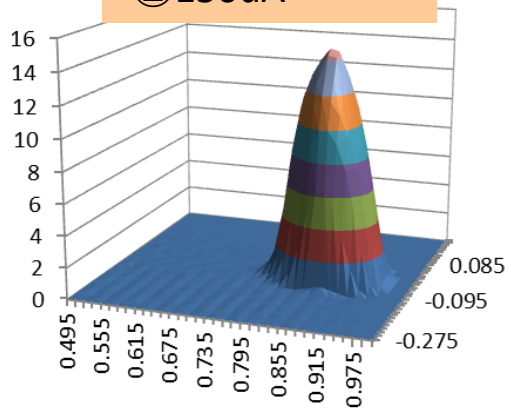
①0.25Eo(1.5uC/cm2)
②250uA



①0.25Eo(1.5uC/cm2)
②150uA

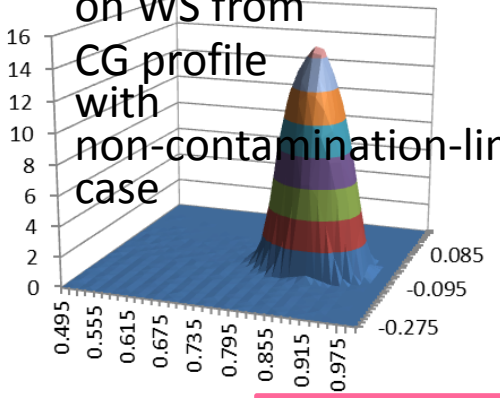


①Eo(6uC/cm2)
②150uA

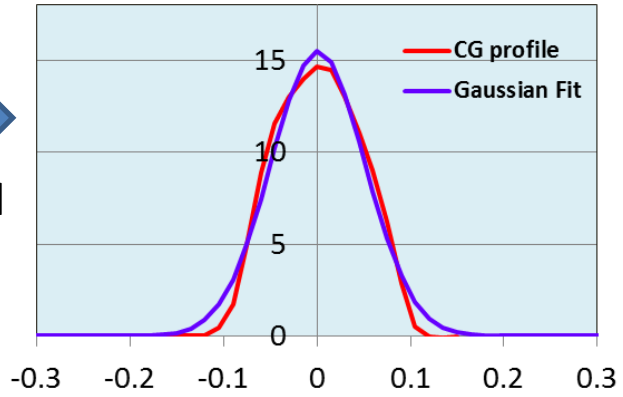


Comparison of contamination-limited condition between A and D

We have estimated EB intensity distribution on WS from CG profile with non-contamination-limited case

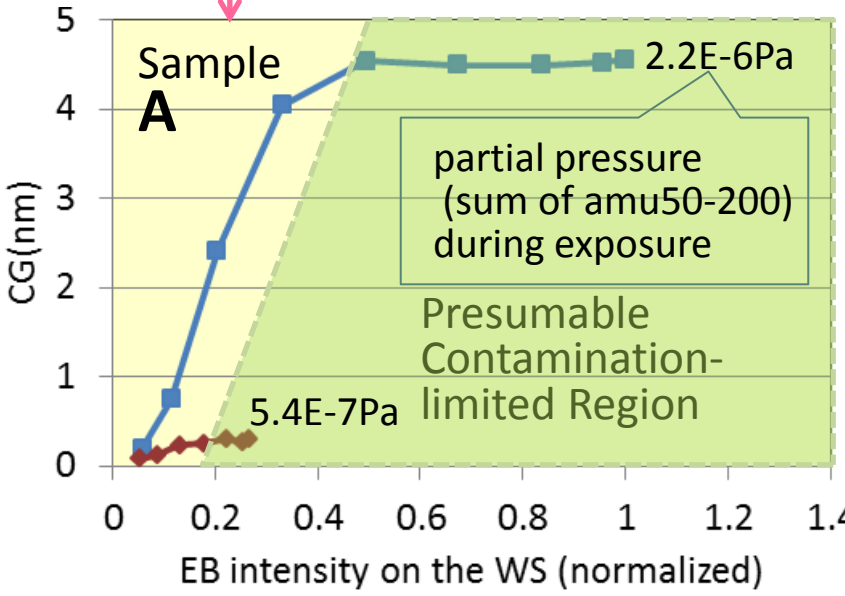


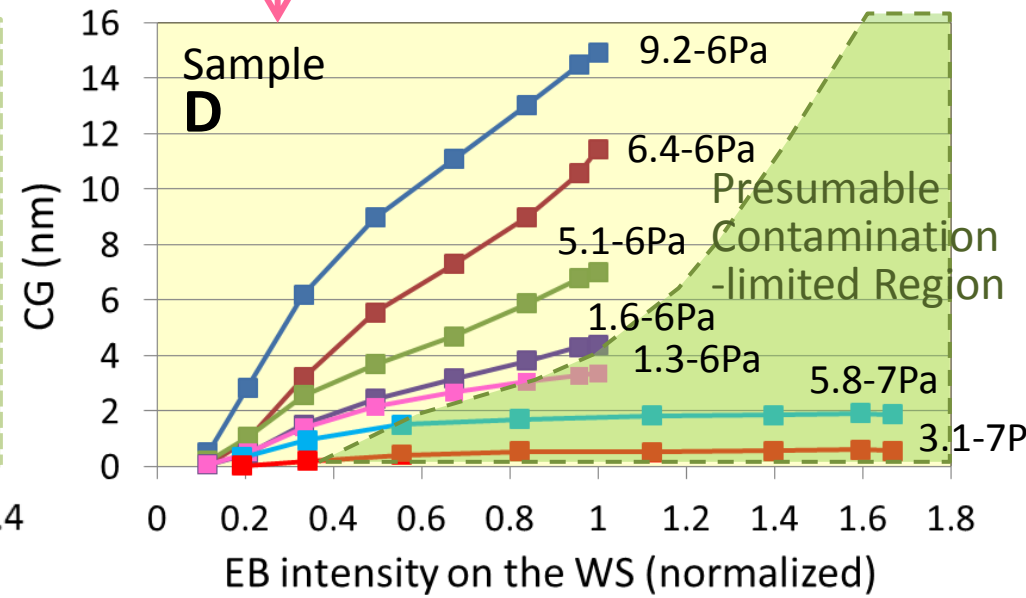
CG profile was fitted to Gaussian



EB Intensity distribution on the WS was assumed to be Gaussian

Relation of CG to EB intensity were obtained for different partial pressure (sum of amu 50-200) during exposure.

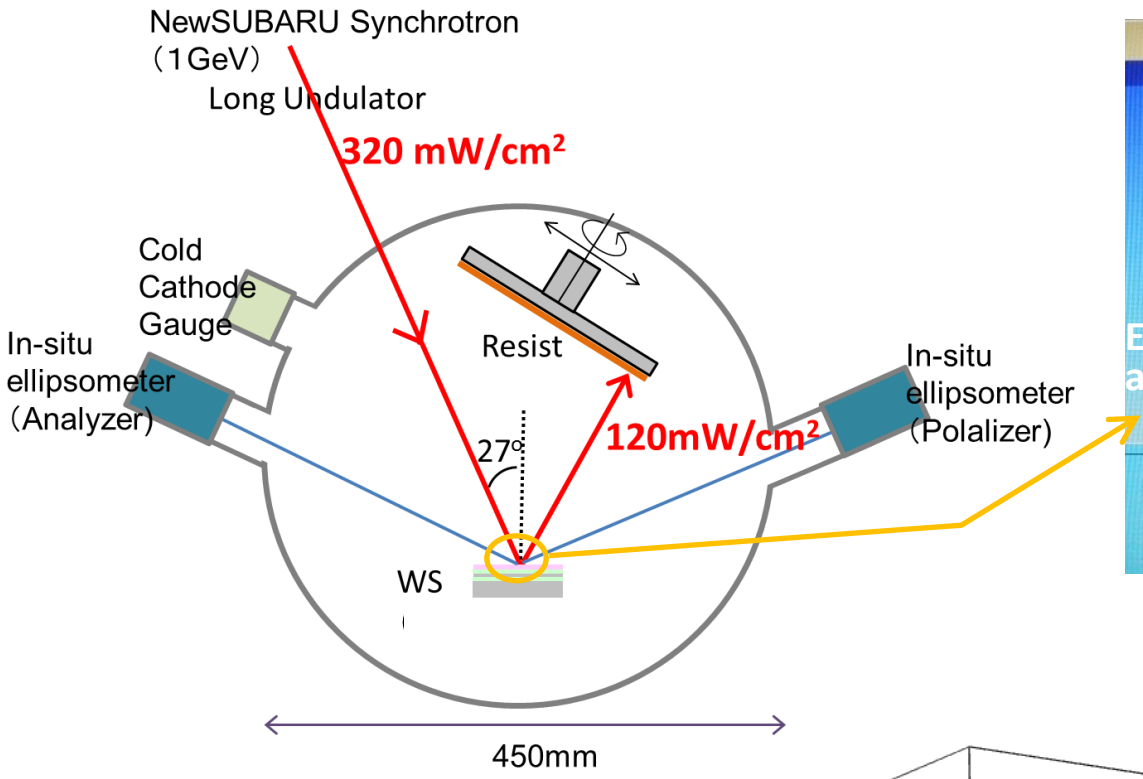




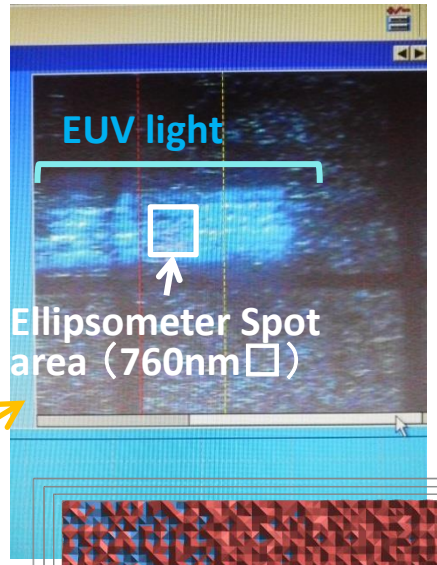
CG vs. EB intensity in the Sample A (left) and Sample D (right)

Contamination-limited condition is highly influenced by the difference of resists

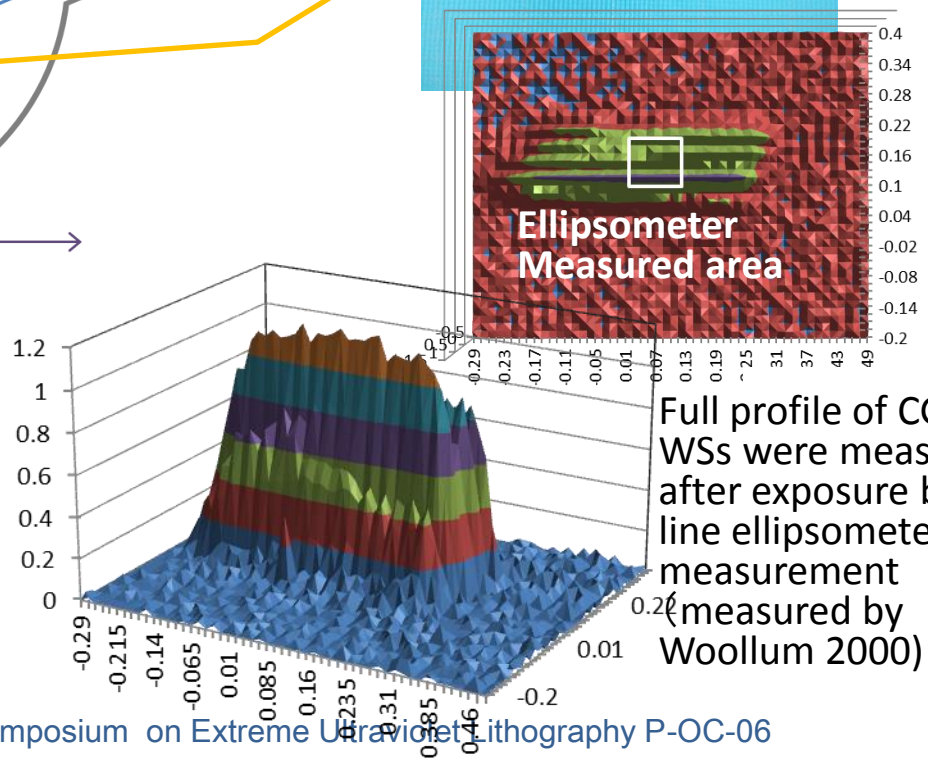
Carbon Deposition Rate Observation by In Situ Ellipsometer in EUV outgas tester



Layout of In-situ ellipsometer (Smart SE, HORIBA) in HERC

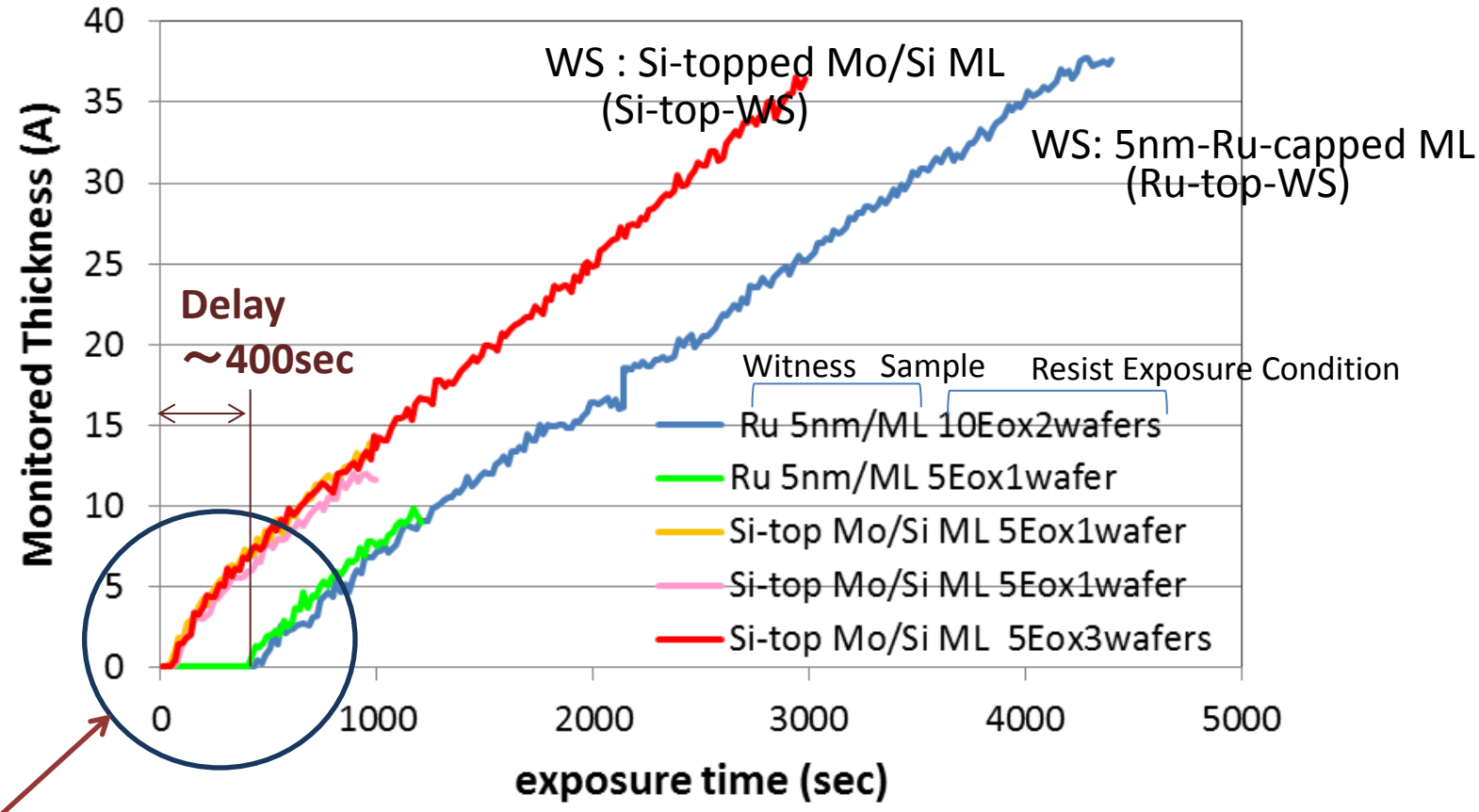


Position of EUV exposure and Ellipsometer spot was alighned using Fluorescent plate



Full profile of CG on WSs were measured after exposure by off-line ellipsometer measurement (measured by Woollum 2000)

Carbon thickness vs. Exposure time monitored by In-situ Ellipsometer



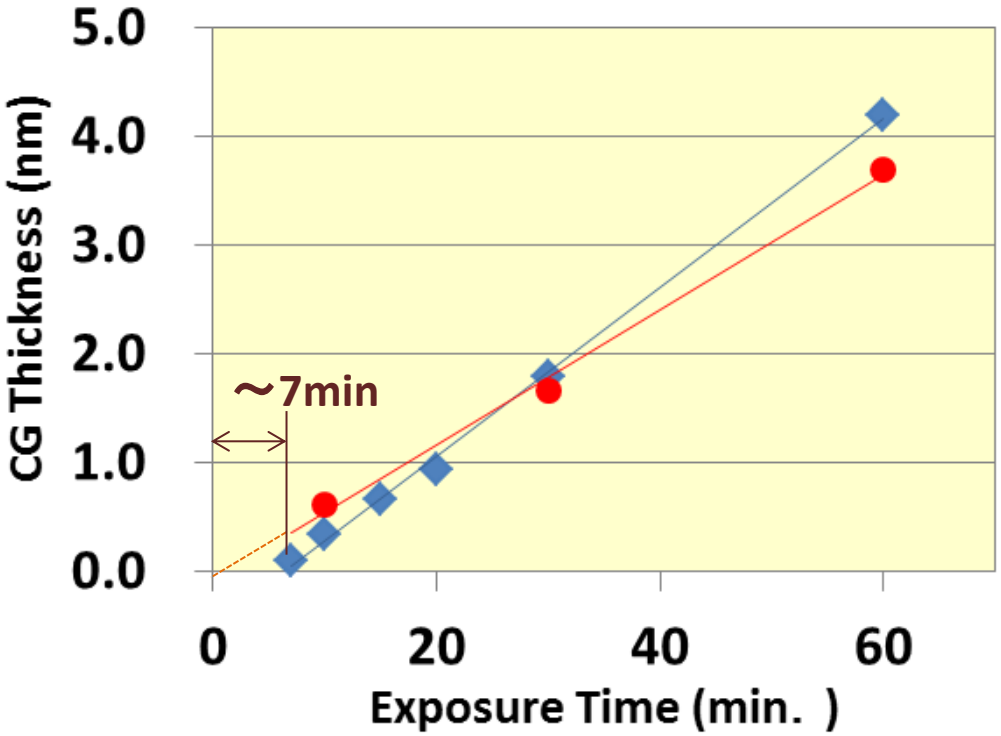
Monitored Carbon thickness vs. Exposure time by Sample D

Delay time of ～400sec on Ru-top-WS was observed by EUV outgas tester.
No delay and faster carbon deposition at the start observed on Si-top WS.

⇨ Same trend was observed for all resist samples with different composition.

Comparison of Ru-top-WS and Si-top-WS by EB tester

For the substitute of in-situ ellipsometer, exposure time was changed for different WSs and the carbon thickness was measured after exposure by EB outgas tester.

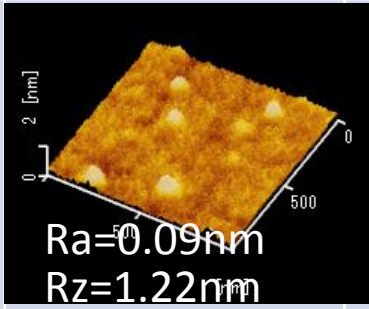
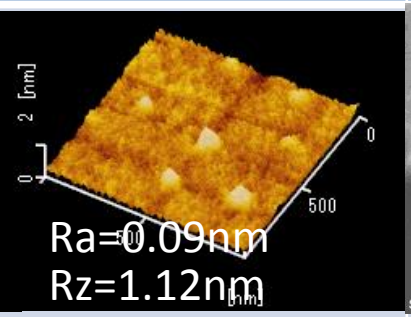
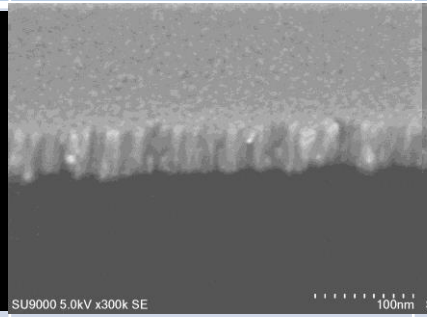
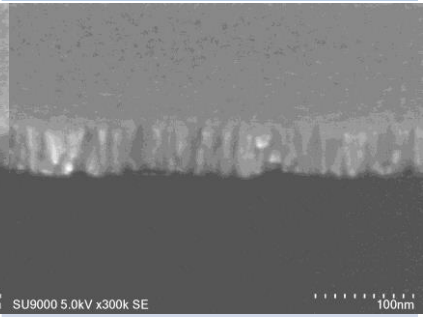
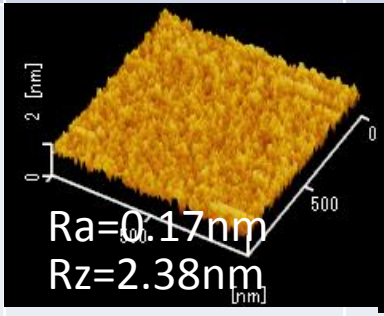
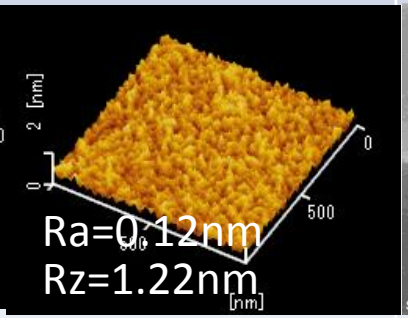
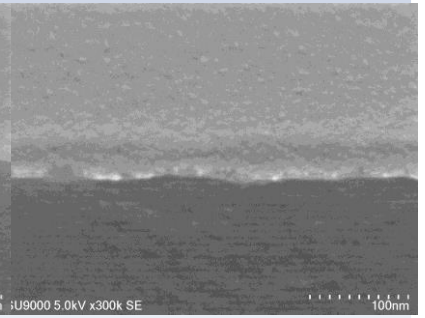
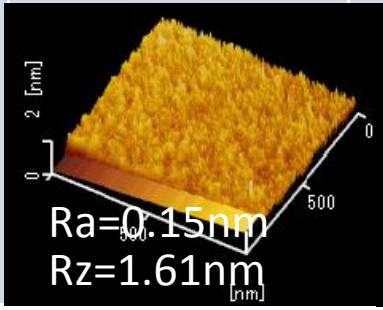
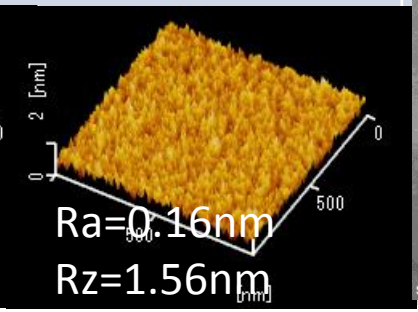
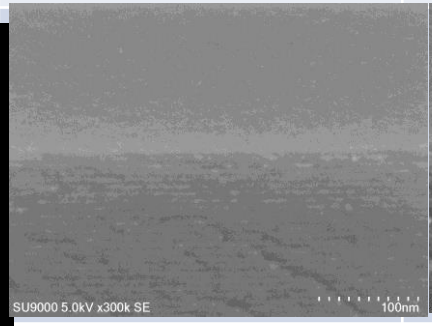
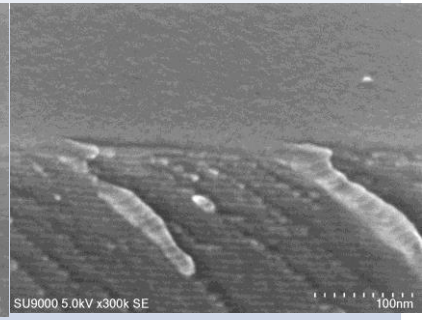


WS: 50nmt-Ru on Si substrate (Ru-top-WS)

WS: Si-top Mo/Si ML (Si-top-WS)

About 7min of delay on Ru-top-WS for CG start after the exposure start was observed also in EB tester.
No delay on the Si-top-WS was also indicated.

Observing WS surface by AFM and X-SEM

WS	Non-Exposure are a by AFM	Carbon deposition area by AFM	Non-Exposure area by X-SEM	Carbon deposition area by X-SEM
50nmt-Ru /Si				
5nm-Ru/ MoSi ML				
Si-top MoSi ML				

Evaluated surface roughness (value of Ra) by AFM does not show remarkable difference between Ru-top and Si-top WSs.
So the reason of the difference observed at the starting feature of carbon deposition might attribute to the reactivity of material.

Summary

1. With the experiments performed by the Witness-Sample method in a EB-outgas tester EUVOM-9000, a big difference was found for the range of contamination -limited condition on the carbon contamination between the resists having different outgassing species and/or amounts.

2. It was found that the kinds of surface material of Witness-Sample cause the difference on the starting feature of carbon deposition.
   On the Ru-top-WS, the delay time of about 7 min. was observed before the deposition starts after the exposure on WS has started, in both of EUV and EB exposure.
   On the other hand, on the Si-top-WS, the deposition rate of carbon was large at the start and then gradually decreased to the definite rate, i.e. that on the thick carbon, at about the 1 nm of carbon deposition.

Acknowledgment

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